

**What Is Claimed Is:**

1. A light emitting diode, comprising:
  - a transparent insulating substrate;
  - a first conductivity type GaN as a first lower cladding layer directly over
  - 5 said transparent insulating substrate;
  - an InGaN light-emitting layer directly over said lower cladding layer;
  - a second conductivity type GaN as second upper cladding layer directly
  - over said InGaN light-emitting layer;
  - a GaN based contact layer with Gallium rich phase and thickness is
  - 10 between 5 Angstroms to 1000 Angstroms directly over said upper cladding
  - layer;
  - an AlGaInSnO system transparent conducting oxide (TCO) as a light
  - transmitting layer directly over said GaN based contact layer, and the
  - thickness of this TCO thin film must over 5 Angstroms;
  - 15 a first electrode formed on the partially exposed area of the first
  - conductivity type GaN; and
  - a second electrode formed on top of the light transmitting layer.
2. A light emitting diode as recited in claim 1, wherein said transparent
- conducting oxide (TCO) has the composition:
  - 20  $\text{Al}_x\text{Ga}_{3-x-y}\text{In}_{5+y}\text{Sn}_{2-z}\text{O}_{16-2z}$ ,
  - Where  $0 \leq x < 2$ ,  $0 < y < 3$ ,  $0 \leq z < 2$ .
3. A light emitting diode as recited in claim 1, wherein said transparent
- insulating substrate is selected from a group consisting of  $\text{Al}_2\text{O}_3$ ,  $\text{LiGaO}_2$ ,
- $\text{LiAlO}_2$  and  $\text{MgAl}_2\text{O}_4$ .
- 25 4. A light emitting diode as recited in claim 1, wherein said GaN based

- contact layer is selected from a group consisting of AlGa<sub>N</sub>, Ga<sub>N</sub>, and InGa<sub>N</sub>.
5. A light emitting diode, comprising:
- a first conductivity type substrate;
  - 5 a first conductivity type Ga<sub>N</sub> as a first lower cladding layer directly over said substrate;
  - an InGa<sub>N</sub> light-emitting layer directly over said lower cladding layer;
  - a second conductivity type Ga<sub>N</sub> as a second upper cladding layer directly over said InGa<sub>N</sub> light-emitting layer;
  - 10 a Ga<sub>N</sub> based contact layer with Gallium rich phase and thickness is between 5 Angstroms to 1000 Angstroms directly over said upper cladding layer;
  - an AlGaInSnO system transparent conducting oxide (TCO) as a light transmitting layer directly over said Ga<sub>N</sub> based contact layer, and the
  - 15 thickness of this TCO thin film must over 5 Angstroms;
  - a first electrode formed underneath the first conductivity type substrate;
  - and
  - a second electrode formed on top of the light transmitting layer.
6. A light emitting diode as recited in claim 5, wherein said transparent
- 20 conducting oxide (TCO) has the composition:
- $$\text{Al}_x\text{Ga}_{3-x-y}\text{In}_{5+y}\text{Sn}_{2-z}\text{O}_{16-2z},$$
- Where  $0 \leq x < 2$ ,  $0 < y < 3$ ,  $0 \leq z < 2$ .
7. A light emitting diode as described in claim 5, wherein said conductivity
- 25 type substrate is selected from a group consisting of SiC, Si, ZnSe, GaAs, GaP, Ga<sub>N</sub> and AlN.

8. A light emitting diode as described in claim 5, wherein said GaN based contact layer is selected from a group consisting of AlGaN, GaN, and InGaN.
9. A light emitting diode, comprising:
  - 5 a transparent insulating substrate;
  - a first conductivity type GaN as a first lower cladding layer directly over said transparent insulating substrate;
  - an InGaN light-emitting layer directly over said lower cladding layer;
  - a second conductivity type GaN as second upper cladding layer directly
  - 10 over said InGaN light-emitting layer;
  - an AlGaInN system intermediate layer directly over said upper cladding layer, with material band-gap energy is lower than the second conductivity type GaN and thickness is between 5 Angstroms to 500 Angstroms;
  - a GaN based contact layer with Gallium rich phase and thickness is
  - 15 between 5 Angstroms to 1000 Angstroms directly over said intermediate layer;
  - an AlGaInSnO system transparent conducting oxide (TCO) as a light transmitting layer directly over said GaN based contact layer, and the thickness of this TCO thin film must over 5 Angstroms;
  - 20 a first electrode formed on the partially exposed area of the first conductivity type GaN; and
  - a second electrode formed on top of the light transmitting layer.
10. A light emitting diode as recited in claim 9, wherein said transparent conducting oxide (TCO) has the composition:
  - 25  $\text{Al}_x\text{Ga}_{3-x-y}\text{In}_{5+y}\text{Sn}_{2-z}\text{O}_{16-2z}$ ,

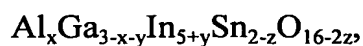
Where  $0 \leq x < 2$ ,  $0 < y < 3$ ,  $0 \leq z < 2$ .

11. A light emitting diode as recited in claim 9, wherein said transparent insulating substrate is selected from a group consisting of  $\text{Al}_2\text{O}_3$ ,  $\text{LiGaO}_2$ ,  $\text{LiAlO}_2$  and  $\text{MgAl}_2\text{O}_4$ .
- 5 12. A light emitting diode as recited in claim 9, wherein said GaN based contact layer is selected from a group consisting of AlGaInN, GaN, and InGaInN.
13. A light emitting diode as recited in claim 9, wherein said intermediate layer is selected from a group consisting of AlGaInN, InGaInN, and InN.
- 10 14. A light emitting diode, comprising:
- a transparent insulating substrate;
  - a first conductivity type GaN as a first lower cladding layer directly over said transparent insulating substrate;
  - an InGaInN light-emitting layer directly over said lower cladding layer;
  - 15 a second conductivity type GaN as second upper cladding layer directly over said InGaInN light-emitting layer;
  - a GaN based contact layer with Gallium rich phase and thickness is between 5 Angstroms to 1000 Angstroms directly over said upper cladding layer;
  - 20 an AlGaInSnO system transparent conducting oxide (TCO) as a light transmitting layer directly over said GaN based contact layer, and the thickness of this TCO thin film must over 5 Angstroms;
  - a transparent conducting oxide window layer directly over said light transmitting layer;
  - 25 a first electrode formed on the partially exposed area of the first

conductivity type GaN; and

a second electrode formed on top of the transparent conducting oxide window layer.

15. A light emitting diode as recited in claim 14, wherein said transparent  
5 conducting oxide (TCO) has the composition:



Where  $0 \leq x < 2$ ,  $0 < y < 3$ ,  $0 \leq z < 2$ .

16. A light emitting diode as recited in claim 14, wherein said transparent  
insulating substrate is selected from a group consisting of  $\text{Al}_2\text{O}_3$ ,  $\text{LiGaO}_2$ ,  
10  $\text{LiAlO}_2$  and  $\text{MgAl}_2\text{O}_4$ .

17. A light emitting diode as recited in claim 14, wherein said GaN based  
contact layer is selected from a group consisting of AlGaN, GaN, and  
InGaN.

18. A light emitting diode as recited in claim 14, wherein said transparent  
15 conducting oxide window layer is selected from a group consisting of  $\text{SnO}_2$ ,  
 $\text{In}_2\text{O}_3$ , ITO,  $\text{Cd}_2\text{SnO}_4$ , ZnO,  $\text{CuAlO}_2$ ,  $\text{CuCaO}_2$ ,  $\text{SrCuO}_2$ , NiO, and  $\text{AgCoO}_2$ .

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